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Advanced education and training in bioenergy in Europe

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ABSTRACT

The paper explains how bioenergy education and training is growing in Europe. Employment estimates are included for renewable energy in general, and bioenergy in particular, to highlight the need for a broadly based education and training programme that is essential to build a knowledgeable workforce that can drive Europe's growing bioenergy sector. The paper reviews current provisions in bioenergy at Masters and PhD levels across the 27 members of the EU (EU27) plus Norway and Switzerland. This identifies a very active and expanding bioenergy education provision. 65 English-language Masters Courses in bioenergy (either focussing completely on bioenergy or with significant bioenergy content or specialisation) were identified. 231 providers of PhD studies in bioenergy were found.

Masters Course offerings have grown rapidly across Europe during the last five years, but where data is available, enrolment has been quite low suggesting that there is an oversupply of courses and that course organisers are being optimistic in their projections. Existing provisions in Europe at Masters and PhD levels are clearly more than sufficient for short term needs, but further work is needed to evaluate the take-up rate and the content and focus of the provisions. To ensure talented graduates are attracted to these programmes, better promotion, stronger links with the research community and industry, and increased collaboration among course providers are needed. Short Courses of two to five days are an excellent way of meeting post-experience training needs but require further growth and development to serve the needs of the bioenergy community.

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1. Introduction

Biomass has the potential to provide a large proportion of the global renewable energy demands and offers opportunities to create substantial employment. If these opportunities are to be realised, there will need to be considerable growth in the dedicated skills needed to support and develop the range of industrial sectors and thus a substantial demand for primary and secondary training and re-training courses. Favourable European Commission (EC) and national policy directives on renewable energy and the expansion of the bioenergy industry have caused significant growth in European bioenergy higher education and training provisions in the last ten years. To review the current field, existing education and

training programmes in bioenergy were mapped by surveying provisions across the 29 countries in the EU27 and Norway and Switzerland.

2. Methodology

The original work in the Bioenergy Network of Excellence (NoE) surveyed both Masters Courses that provided:

1. Postgraduate courses on biomass and/or bioenergy and/or biofuels, or which included at least some material on one or more of these topics

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2. Research provision in biomass and/or bioenergy and/or biofuels at doctorate level.

This initial work only covered the eight countries that were represented by partners in the NoE project – Austria, Finland, France, Germany, Netherlands, Poland, Sweden and UK. Towards the end of the six year project, as a number of new instruments were introduced in Europe, it became clear that a pan-European analysis was required in order to establish a framework for either continued activity for the Bioenergy NoE and/or as a resource for the new instruments that could address education and training issues in the coming years. The scope was therefore expanded to cover all countries in the EU27 plus Norway and Switzerland.

Information was gleaned from members of the project, from analogous work carried out in ThermalNet [1], from a thorough search on the internet, and from contributions to conferences and the literature. It became clear that although the survey was as thorough as possible, it seems likely that a significant although minor fraction of the activities is probably not included.

For undergraduate courses, a survey of a wide range of potential employers confirmed a clear view that existing first degree courses in traditional science and engineering disciplines were the best possible training prior to specialisation at masters or doctorate levels. Some companies expressed a view that a short basic familiarisation module might be useful but not more than about 10% of one year's credits. Since first degree courses (such as BSc, BEng) etc are widely promoted with extensive information available through the internet and universities' own promotion, this aspect has not been included.

3. Employment from bioenergy in the EU

In order to set this activity into context, employment estimates are included for renewable energy in general, and bioenergy in particular, to highlight the need for an education and training programme that can provide a sound human resource base for the bioenergy industry.

A bioenergy system comprises biomass production, biomass conversion to a higher quality energy product and use of the energy product for power, heat, transport fuels and/or chemicals. Within this overall system, the biomass production step is particularly labour intensive on farms and in forests, while the conversion and utilisation steps are capital intensive often with a high level of automation that reduces overall labour requirements but requires advanced skills. In comparison to fossil fuels in Europe, biofuels create 50–100 times the number of jobs; electricity from biomass creates 10–20 times the number of jobs; and heat from biomass creates double the number of jobs [2]. This is because bioenergy processes are often distributed and therefore require more labour than conventional energy production processes. Other references support the claim of substantial job creation [3,4].

There is broad agreement that bioenergy will provide substantial new job opportunities but there is considerable variability in the absolute numbers. This section summarises

some of the major findings and provides a brief summary of a more detailed study, the MITRE 2004 report, to indicate where along the bioenergy chain most jobs will be created in the bioenergy, waste and agricultural sectors, and the expected ratio of skilled to unskilled jobs [3].

The EC's Biomass Action Plan published in December 2005 estimated that if Europe meets the target to increase bioenergy to 6.3 exajoules of energy by 2010 from 2.9 exajoules of energy in 2005, it would directly create 250–300,000 new jobs, mainly in rural areas [2].

The European Renewable Energy Council (EREC) study "Renewable Energy Target for Europe: 20% by 2020," projects that 1,067,000 new jobs in renewable energy will be created by 2010 if the former EU15 meets its bioenergy targets. Of these 762,000, or 71%, will be in bioenergy with 338,000 in biomass and another 424,000 in biofuels. If Europe meets the target of 20% energy from RES in 2020, the study estimates a further 380,000 jobs will be created in the bioenergy industry [4].

The MITRE Overview Report provides a deeper insight into job creation from bioenergy in the EU15. The study projected employment growth from renewable energy from 2000 to 2010 and from 2000 to 2020 under two different scenarios. Each scenario includes an analysis of employment by Member State, by technology and by skill level in the former EU15 [3]. Two scenarios were considered – current policies and advanced renewable strategy. The majority of all new jobs from renewable energy will be in biomass and biofuels and agricultural fuel supply from energy crops, wood residues and agricultural wastes (Table 1).

Table 1 organises employment projections under the "Current Policies" scenario (if energy from biomass grows according to current policies and those expected to be implemented). Under this scenario for 2010 about 798,000 jobs will be created in bioenergy. Of these 422,000 jobs will be created in the biomass and biofuels sectors, 56,000 in biogenic wastes and biogas and 320,000 in the agricultural sector to supply energy crops, forest residues and agricultural wastes.

Employment projections under the "Advanced Renewable Energy Strategy" scenario (if bioenergy is pushed to meet its 2010 targets by a variety of proactive policies) are also outlined in Table 1. This scenario estimates that by 2010 biomass and biofuels production could open up 695,000 new jobs and provide another 699,000 in the agricultural sector and 67,000 in the wastes and biogas sector. In both scenarios employment from bioenergy supply and production is projected to account for at least 84% of the total new jobs created in the renewable industry by 2010.

The MITRE study provides a breakdown of skilled and unskilled jobs from the total number of renewable energy jobs created in each EU15 country. Table 2 outlines the percentage of skilled employment estimated to come from new jobs in renewable energy in each of the EU15 countries.

More research is needed to determine the number of skilled jobs expected in bioenergy, but clearly demand for highly skilled labour, particularly in the conversion and utilisation steps, will grow as the bioenergy market expands. To fill the demand it is essential that there are enough high quality advanced courses in place and enough students attracted to the bioenergy field.

Table 1 – Total projected employment growth for the EU15 in renewable energy from 2000 to 2010 and 2020 under current policies scenario and advanced renewable energy scenario. MITRE [3].

Employment by sector (full-time equivalent)	Current policies		Advanced renewable energy strategy	
	2010	2020	2010	2020
Biomass	210,000	268,000	271,000	334,000
Biofuels	212,000	354,000	424,000	614,000
Wastes/biogas	56,000	67,000	67,000	83,000
Agriculture	320,000	550,000	699,000	1,039,000
Bioenergy industry subtotal	798,000	1,239,000	1,461,000	2,070,000
Small hydro	16,000	21,000	15,000	23,000
Wind	182,000	162,000	282,000	368,000
Photovoltaics	9000	20,000	31,000	103,000
Geothermal	2000	3000	5000	10,000
Solar thermal	27,000	37,000	90,000	97,000
Other	0	3000	0	12,000
Support mechanisms	–85,000	–41,000	–225,000	–220,000
Total renewable industry	949,000	1,444,000	1,659,000	2,463,000
% contribution of bioenergy to total renewable energy employment	84%	86%	88%	84%
Annual growth rate in employment		15%		15%

4. Review of advanced bioenergy education and training in Europe

A comprehensive review of all Masters Courses and PhD research activities in biomass, bioenergy and biofuel has been carried out. The results are summarised in Table 3 for English-language Masters Courses on biomass, bioenergy and biofuels (including part provision) and Table 4 for PhD providers in the same areas. This review identified 65 English-language Masters Courses in or with significant bioenergy content and 231 providers of PhD studies. Postgraduate provision is a high growth area, with the majority of Masters and Short Courses currently on offer being initiated in the last five years.

Table 2 – Skilled employment from total renewable energy employment by 2010 and 2020 in seven countries and the EU15 average [5].

Country	Percentage of skilled employment from renewables in 2010	Percentage of skilled employment from renewables in 2020
Austria (AT)	24%	24%
Belgium (BE)	37%	32%
Denmark (DK)	43%	42%
Finland (FI)	30%	31%
France (FR)	27%	30%
Germany (DE)	32%	33%
Greece (GR)	13%	13%
Ireland (IE)	18%	20%
Italy (IT)	20%	18%
Luxembourg (LU)	18%	22%
Netherlands (NL)	22%	25%
Portugal (PT)	31%	28%
Spain (ES)	19%	23%
Sweden (SE)	35%	40%
United Kingdom (UK)	33%	34%
EU15	28%	28%

Four constraints were put on this mapping exercise:

1. In order to be listed, Masters Courses had to offer at least one module on biomass, bioenergy or biofuel, or a major research project on a biomass or bioenergy topic. A module is defined as typically 100 h student learning time of which around 25% is direct contact with a teacher.
2. Only English language based taught Masters Courses were included. PhD studies in any European language were included in order to capture a good range of current activities.
3. Lists of Masters Courses, PhD topics completed over the last five years were collected from contacts in many countries, from the internet and by personal correspondence with education providers. As explained above, the results are comprehensive but may not be exhaustive.

4.1. Masters courses

65 English-language taught Masters Courses were identified in the EU27 plus Norway and Switzerland that include at least some bioenergy content and a full listing can be found in Table 3. It is important to note that there are additional Masters Courses offered in native languages of the partner countries, but these were not included since their international appeal is limited. The data shows the net increases in MSc Courses that allow for cessation of courses.

The growth in MSc Courses from 1987 to 2009 is summarised in Fig. 1 for the eight countries that made up the Bio-energy NoE (Austria, Finland, France, Germany, Netherlands, Poland, Sweden and UK). Fig. 2 shows the geographical distribution of these courses in 2009.

4.1.1. Masters courses findings

To help identify and explain key trends in bioenergy higher education provision in Europe, this study investigated the emergence of Masters Courses in bioenergy over the last 30 years. Taught bioenergy education in Europe grew very slowly

Table 3 – MSc providers in bioenergy by country 2009. This is a list of known Masters Course providers in the 27 countries of the EU and Norway and Switzerland. The list has been compiled from the internet, from conference proceedings, and from publications. Any omissions are not deliberate, nor are any research providers listed afforded any endorsement by the authors. The authors would be pleased to hear of any omissions or inaccuracies as this is an ongoing project.

Institution(s)	Course title	Website
<i>Austria</i>		
University of Applied Science, Burgenland.	Sustainable energy systems.	http://www.fh-burgenland.at/
University of Leoben, Styria.	Natural resources with the main area: raw materials and energy systems.	http://www.mu-leoben.at/
University of Natural Resources and Applied Life Sciences, Vienna.	Agricultural and food economics; biotechnology; environmental engineering; forest science; land management; management of land; environment and bioresources; wood technology and management.	http://www.boku.ac.at/
Vienna University of Technology + others.	Renewable energy in central & eastern Europe.	http://www.tuwien.ac.at/
<i>Belgium</i>		
EUREC + others.	Renewable energy, biomass specialisation.	http://www.eurec.be/
Ghent University + others.	Renewable resources.	http://www.synbioc.ugent.be/
<i>Croatia</i>		
University of Zagreb + others.	Sustainable power generation.	http://www.fsb.hr/see/
<i>Denmark</i>		
Aalborg University.	Sustainable energy engineering.	http://en.aau.dk/
Technical University of Denmark.	Sustainable energy including biofuels.	http://www.dtu.dk/
<i>Estonia</i>		
Estonian University of Life Science.	Renewable energy resources.	http://www.emu.ee/
<i>Finland</i>		
Åbo Akademi.	Biofuel option.	http://web.abo.fi/
Finnish–Russian Cross-Border University.	Forestry and environmental engineering (contains at least two bioenergy modules).	http://cbu.fi/en/
Lappeenranta University of Technology with University of Joensuu.	Bioenergy technology.	http://www.lut.fi/
University of Jyväskylä + others.	Renewable energy.	http://www.jyu.fi/
<i>France</i>		
École des Mines de Paris, Paris.	Renewable energy.	http://www.ensmp.fr/masteres/
Ecole Nationale Supérieure d'Arts et Métiers, Corsica.	Renewable energy and production system.	http://www.bastia.ensam.fr/
ISAB-IGAL – Institut Supérieur d'Agriculture de Beauvais.	Agriculture, agrobusiness and bioresources.	http://www.lasalle-beauvais.fr/
Polytech Savoie, University of Savoie, Le Bourget Du Lac.	Ecotechniques speciality recovery of renewable energy and waste.	http://www.polytech.univ-savoie.fr/
University Paris Est, Marne-La-Vallée.	Energy, option in renewable energy.	http://www.univ-mlv.fr/
<i>Germany</i>		
Albert-Ludwigs University of Freiburg.	Renewable energy management.	http://www.zee-uni-freiburg.de/
BTU Cottbus (Brandenburg University of Technology).	Energy from biomass and waste.	http://www.tu-cottbus.de/
Carl-von-Ossietzky University, Oldenburg.	Renewable energy.	http://www.ppre.de/
Hamburg University of Technology (TUHH).	Biochemical and chemical engineering.	http://www.tu-harburg.de/
RWTH Aachen University.	Biogas and biohydrogen.	http://www.biotec.rwth-aachen.de/
Stuttgart University.	Environmental engineering, waste, solid waste specialisation.	http://www.waste.uni-stuttgart.de/
Ulm University.	Energy science and technology.	http://www.uni-ulm.de/
University of Applied Sciences, Offenburg.	Energy conversion and management.	http://fh-offenburg.de/
University of Flensburg.	Sustainable energy systems and management.	http://www.uni-flensburg.de/sesam/index.htm
<i>Hungary</i>		
Central European University.	Environmental sciences, policy and management with bioenergy and renewable energy options.	http://www.mespom.org/

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Table 3 (continued)

Institution(s)	Course title	Website
<i>Ireland</i>		
Dundalk Institute of Technology.	Renewable energy systems.	http://ww2.dkit.ie/
<i>Italy</i>		
Polytechnic University of Milan.	Renewable energy and advanced energy systems.	www4.ceda.polimi.it/
University of Florence.	Environmental Science – including biofuels.	http://www.gitasu.com/
<i>Netherlands</i>		
University of Groningen.	Energy and environmental sciences.	http://www.rug.nl/
University of Twente.	Sustainable energy technology.	http://set.graduate.utwente.nl/
Utrecht University.	Energy science and sustainable development.	http://www.uu.nl/
Wageningen University.	Agricultural and bioresource engineering; biotechnology.	http://www.mab.wur.nl/ ; http://www.mbt.wur.nl/
<i>Poland</i>		
University of Science and Technology – AGH, Krakow.	Environmental engineering with specialisation in renewable energy sources.	www.syllabus.agh.edu.pl/
<i>Spain</i>		
University of Cordoba, Spain.	Materials for energy storage and conversion.	www.uco.es/
<i>Sweden</i>		
Chalmers University of Technology.	Integrated biorefinery and sustainable development and energy systems.	http://www.chalmers.se/en/
Royal Institute of Technology. (Kungliga Tekniska Högskolan, KTH).	Sustainable energy engineering with power generation specialisation.	http://www.energy.kth.se/
Luleå University.	Sustainable energy engineering, including bioenergy specialisation.	http://www.ltu.se/
Lund University.	Renewable energy, bioenergy and bioenergy systems.	http://www.iiee.lu.se/ ; http://www.lumes.lu.se/
Mälardalen University.	Renewable energy including bioenergy.	http://www.mdh.se/
University College of Borås.	Sustainable development, resource recovery and biotechnology.	http://edu.hb.se/
University of Uppsala.	Chemistry for renewable energy including materials and methods for developing renewable energy.	http://www.fotomol.uu.se/
<i>UK</i>		
Brunel University.	Sustainable energy: technologies & management.	www.brunel.ac.uk/
Cardiff University.	Sustainable energy and environment.	www.cardiff.ac.uk/
Cranfield University.	Energy systems and thermal processes.	http://www.cranfield.ac.uk/
De Montfort University.	Climate change and sustainable development.	www.iesd.dmu.ac.uk/
Glasgow Caledonian.	Energy & environmental management.	http://hp1.gcal.ac.uk/
Lancaster University.	Low carbon energy.	http://www.engineering.lancs.ac.uk/
London South Bank University.	Sustainable energy systems.	http://prospectus.lsbu.ac.uk/
Loughborough University.	Renewable energy systems technology.	http://www.lboro.ac.uk/
Newcastle University.	Sustainable chemical engineering.	http://www.ncl.ac.uk/
Queen Mary, University of London.	Sustainable energy systems.	http://www.eng.qmul.ac.uk/
University of Dundee.	Renewable energy.	http://www.dundee.ac.uk/
University of Edinburgh.	Sustainable energy systems.	http://www.see.ed.ac.uk/
University of Essex.	Biotechnology: future crops for food and biofuels.	http://www.essex.ac.uk/
University of Glamorgan.	Renewable energy and resource management.	www.glam.ac.uk/
University of Nottingham.	Energy conversion and management.	http://pgstudy.nottingham.ac.uk/
University of Reading.	Renewable energy: technology & sustainability.	http://www.rdg.ac.uk/
University of Salford.	Sustainable development, energy and management.	http://www.salford.ac.uk/
University of Sheffield.	Environmental and energy engineering.	http://www.shf.ac.uk/
University of Surrey.	Renewable energy systems engineering module overview.	http://www.surrey.ac.uk/
University of Ulster.	Renewable energy and energy management.	http://prospectus.ulster.ac.uk/
<i>Useful websites</i>		
Mastersportal.eu		http://www.mastersportal.eu/
MasterGuide.org		http://www.masterguide.org/
Find a masters.com		http://www.findamasters.com/
Next scholarships.com		http://nextscholarships.com/
Scholarship positions.com		http://scholarship-positions.com/

Table 4 – PhD providers in bioenergy by country 2009. This is a list of known research providers in the 27 countries of the EU and Norway and Switzerland who offer PhD or equivalent degrees. The list has been compiled from the internet, from conference proceedings, and from publications. Any omissions are not deliberate, nor are any research providers listed afforded any endorsement by the authors. The authors would be pleased to hear of any omissions or inaccuracies as this is an ongoing project.

Institution(s)	Topic	Website
<i>Austria</i>		
Karl Franzens University of Graz.	Biodiesel from alternative feedstocks.	http://www.uni-graz.at/
Technical University of Graz.	Second generation biofuels by gasification; combustion; thermal biomass utilisation and biorefineries.	http://portal.tugraz.at/ ; http://www.ipe.tugraz.at
University of Leoben.	Biochar respectively bio-coke from agricultural wastes for metallurgical uses.	http://www.unileoben.ac.at/
University of Applied Science for Environment, Innsbruck.	Gasification plants.	http://www.mci.edu/en/
University of Natural Resources and Applied Life Sciences (BOKU), Vienna.	Biomass fuels for heat and CHP.	http://www.boku.ac.at/
Vienna University of Technology.	Steam gasification of biomass, second generation biofuels.	http://www.vt.tuwien.ac.at/
<i>Belgium</i>		
Artesis University College Antwerp.	Saccharification and fermentation of cellulose to ethanol.	http://www.artesis.be/
Catholic University of Leuven.	Fluid bed research relating to fast pyrolysis.	http://www.kuleuven.be/english/
Free University of Brussels.	Bioethanol, bioenergy systems.	http://www.ulb.ac.be/
Gembloux Agricultural University.	In vitro clonal propagation of promising agrofuel producing plants.	http://www.fsagx.ac.be/
Ghent University.	Biomass pyrolysis and related processes.	http://www.ugent.be/en
Hasselt University.	Flash pyrolysis.	http://www.uhasselt.be/en
KaHo Sint-Lieven University College, Ghent.	Pure plant oil production.	http://www.kahosl.be/
Karel de Grote University College, Antwerp.	Pure plant oil production.	http://www.kdg.be/
University College Ghent.	Energy crops for bioethanol production.	http://english.hogent.be/
University of Antwerp.	Micro organisms cumulating bio-oils.	http://www.artesis.be/
University of Namur.	Bioenergy in agriculture.	http://www.fundp.ac.be/
Vrije University, Brussels.	Combustion for small scale applications.	http://www.vub.ac.be/
<i>Bulgaria</i>		
University Assen. Zlatarov.	Biomass fuels for heat and CHP. Biofuels in transport sector.	http://www.btu.bg/
<i>Cyprus</i>		
Technical University of Ostrava, Poruba.	Combustion.	http://en.vsb.cz/
<i>Czech Republic</i>		
Brno University of Technology.	Gasification of biomass.	http://www.vutbr.cz/
<i>Denmark</i>		
Aalborg University, Esbjerg.	Biorefinery systems.	http://en.aau.dk/
Technical University of Denmark.	Pyrolysis and gasification of straw.	http://www.dtu.dk/
University of Copenhagen.	Biorefinery systems. Pellet production processes.	http://www.life.ku.dk/
University of Southern Denmark.	Biogas.	http://www.sdu.dk/
<i>Estonia</i>		
Estonian University of Life Sciences.	Methanogenic potential of crops and wastes.	http://www.emu.ee/
<i>Finland</i>		
Aalto University School of Science and Technology.	Fluid bed combustion and gasification. Waste treatment, CO ₂ sequestration, biofuels, hydrodeoxygenation and catalytic upgrading of pyrolysis liquids. Recombinant fermentation process for L-xylulose synthesis.	http://www.tkk.fi/en/
Åbo Akademi University.	Fluidised-bed combustors, gasifiers and biofuels.	http://www.abo.fi/

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Table 4 (continued)

Institution(s)	Topic	Website
Helsinki University of Technology.	Fluid bed combustion and gasification.	http://energia.tkk.fi/
Lappeenranta University of Technology.	Waste treatment, CO ₂ sequestration, biofuels, hydrodeoxygenation and catalytic upgrading of pyrolysis liquids.	http://www.lut.fi/
Mikkeli University of Applied Sciences.	Biomass; biofuels; domestic and international biofuel trade and bioenergy business models.	http://www.mamk.fi/
University of Eastern Finland – Kuopio.	Biomass and biofuels.	http://www.uku.fi/
University of Helsinki.	Combustion.	http://www.helsinki.fi/
University of Joensuu.	Feedstocks for biological methane and bioethanol production.	http://www.forest.joensuu.fi/
University of Jyväskylä.	Bioenergy system studies, modelling and technology in the forest industry.	http://www.jyu.fi/
University of Oulu.	Bioenergy from wood fuels; fluidised-bed combustion, pyrolysis; production of chemicals from biomass.	http://www.oulu.fi/
University of Turku.	Biomass, biofuel and wood ash in energy production.	http://www.utu.fi/en/
University of Vaasa.	Char production and characterisation.	http://www.uwasa.fi/
France		
Artois University.	Biogas from solid wastes.	http://www.univ-artois.fr/
Centre National de la Recherche Scientifique – ENSIC.	Emerging technologies for biomass use.	http://www.cnrs.fr/
Ecole des Mines de Douai + others.	Thermal analysis.	http://www.gemtech.fr/
Ecole des Mines de Nantes.	Waste and biomass fuels.	http://www.mines-nantes.fr/en/
Ecole Nationale Supérieure de Chimie de Rennes.	Energy engineering – development of biofuels.	http://www.ensc-rennes.fr/
Ecole Polytechnique.	Hydropyrolysis oil characterisation.	http://www.polytechnique.edu/
Haute Alsace University.	Pyrolysis oils from biomass.	http://www.uha.fr/
Nancy University.	Biomass combustion; solid biofuels.	http://www.univ-nancy2.fr/
Paris-Dauphine University.	Pyrolysis and gasification.	http://www.dauphine.fr/
University of La Rochelle.	Knowledge governance for exploration in bio-base activities.	http://www.univ-larochelle.fr/
University of Lyon.	Biological conversion, fermentation, enzymatic processes.	http://www.univ-lyon1.fr/
University of Nancy.	Hydrogen production from biomass.	http://www.univ-nancy2.fr/
University of Pau and Pays de l'Adour.	Microgeneration technology with biomass.	http://www.univpau.fr/
University of Reims Champagne-Ardenne.	Gasification, biomass torrefaction.	http://www.univ-reims.fr/
University of Science and Technology, Lille.	Economics and benefits driving from biomass integration.	http://www.univ-lille1.fr/
University of Technology of Compiègne.	Biorefineries and industrial materials.	http://www.utc.fr/
University of Toulouse.	Anaerobic digestion, biomass pyrolysis.	http://www.univtoulouse.fr/
	Sunflower biorefinery technology.	
	Gasification by flash pyrolysis.	
Germany		
Bielefeld University.	Engineering carbon utilisation of amino acid producing <i>Corynebacterium glutamicum</i> .	http://www.unibielefeld.de/
Brandenburg Technical University, Cottbus.	Solid biofuel production. Pellet production processes.	http://www.tu-cottbus.de/
Flensburg University of Applied Sciences.	Anaerobic digestion.	http://www.fh-flensburg.de/
Heinrich-Heine University, Düsseldorf.	Industrial biotechnology.	http://www.uni-duesseldorf.de/
Leibniz University of Hannover.	Biotechnology for flavour synthesis.	http://www.uni-hannover.de/
Leuphana University of Lüneburg.	Biomass production.	http://www.leuphana.de/
Martin Luther University, Halle-Wittenberg.	Plasticized cellulose acetate for foaming applications.	http://www.uni-halle.de/
Munich University of Applied Science.	Research on algae growth.	http://www.hm.edu/
RWTH Aachen University.	Liquid biofuels from oil seeds.	http://www.rwth-aachen.de/
Saarland University of Applied Science.	Biomass and municipal solid waste.	http://www.erneuerbareenergien.saarland.de/
Stuttgart University.	Biomass energy; gasification.	http://www.ier.uni-stuttgart.de/
Technical University of Bergakademie Freiberg.	Environmental and material science, technology and management.	http://www.phd.tu-freiberg.de/

Table 4 (continued)

Institution(s)	Topic	Website
Technical University of Berlin.	Process, energy; environmental, control engineering; process and plant technology.	http://www.pipes-berlin.org/
Technical University of Clausthal.	Characterisation of fuels, fuel analysis, slagging, reactivity and sintering temperature.	http://www.tu-clausthal.de/
Technical University of Hamburg.	Pyrolysis of rape-seed in a fluidised-bed reactor.	http://www.tu-harburg.de/
Technical University of Munich.	Catalytic conversion of phenolic bio-oil to alkanes. Algae research.	http://portal.mytum.de/welcome
TU Dortmund University.	Biocatalysis and enzyme technology.	http://www.tu-dortmund.de/
University of Applied Sciences, Münster.	Bioethanol production.	https://en.fh-muenster.de/
University of Applied Science, Nürtingen, Stuttgart.	Economics and benefits driving from biomass integration.	http://www.hfwu.de/
University of Applied Sciences, Oldenburg.	Synthesis of monomers and polymers from renewable resources.	http://www.fh-oow.de/english/
University of Applied Sciences, Weihenstephan, Straubing.	Biobased products and consumer behaviour.	http://www.hswt.de/
University of Applied Sciences, Wildau.	Biomass gasification.	http://www.th-wildau.de/
University of Hohenheim.	Biofuels from sugars and starch.	https://www.uni-hohenheim.de/
University of Kaiserslautern.	Anaerobic production of ABE solvents from oils adsorbed to bleaching earth.	http://www.uni-kl.de/
University of Karlsruhe.	Heat and mass transfer in fluidised beds.	http://www.uni-karlsruhe.de/
University of Kassel.	Biomass gasification.	http://cms.uni-kassel.de/
University of Konstanz.	Sustainability of biofuels.	http://www.uni-konstanz.de/
University of Oldenburg.	Developments in Fischer–Tropsch processes.	http://www.uni-oldenburg.de/
University of Regensburg.	Second generation biofuel.	http://www.uni-regensburg.de/
University of Siegen.	Biomass gasification.	http://www.uni-siegen.de/start/
University of Stuttgart.	Biobased polymers.	
<i>Greece</i>		
Agricultural University of Athens.	Research on energy crops and algae. Solid biofuels.	http://www.aua.gr/
Aristotle University of Thessaloniki.	Pyrolysis liquid analysis, pyrolysis liquid upgrading, steam reforming pyrolysis liquid.	http://www.auth.gr/
National Technical University of Athens.	Gasification. Enzymatic processes.	http://www.ntua.gr/
Technical University of Crete.	Biodiesel production from olive pomace oil.	http://en.tuc.gr/
University of Ioannina, Agrinio.	New plants and equipment for biomass.	http://www.uoi.gr/
University of Patras.	Catalysis. Sunflower and rape-seed residues for methane production.	http://www.upatras.gr/
University of Piraeus.	Biomass chemistry, 2nd generation biofuels.	http://www.unipi.gr/
University of Thessaly.	Research on energy crops.	http://www.uth.gr/
<i>Hungary</i>		
Budapest University of Technology and Economics.	Co-combustion of biomass. Second generation biofuels.	http://portal.bme.hu/
Central European University.	External influences on bioenergy industries in transition economies.	http://www.ceu.hu/
Hungarian Academy of Science.	Thermogravimetric analysis, pyrolysis	http://www.mta.hu/
University of Miskolc.	Ligneous biomass. Combustion and co-combustion.	http://www.uni-miskolc.hu/
University of Pannonia.	Biodiesel production.	http://www.uni-pannon.hu/
<i>Ireland</i>		
Trinity College, Dublin.	Transport, energy and environment. Biomass production.	http://www.tcd.ie/
University College Dublin.	Biomass resources.	http://www.ucd.ie/
University of Limerick.	Biomass and biofuels. Levulinic acid. Gasification. Pyrolysis.	http://www.ul.ie/

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Table 4 (continued)

Institution(s)	Topic	Website
<i>Italy</i>		
Catholic University of the Sacred Heart.	Research on energy crops – sweet sorghum.	http://www.unicatt.it/
Economics University of Bari.	International trade of biomass.	http://www.dse.uniba.it/
Marche Polytechnic University.	Biomass gasification.	http://www.univpm.it/
Polytechnic of Milan.	Thermolysis of waste sludges to enhance biogas production.	http://www.english.polimi.it/
Polytechnic of Torino.	Biological conversion, fermentation, enzymatic processes.	http://www.diter.polito.it/
Polytechnic University of Marche.	Lipids production from microalgae.	http://www.finnov-fp7.eu/
Tor Vergata University, Rome.	Biomass gasification.	
	Liquefied wood – advanced characterisation of lignin based polymer.	http://web.uniroma2.it/
University of Bologna.	Anaerobic digestion.	http://www.unicatt.it/
	Energy crops and algae.	
University of Calabria.	Biological conversion, fermentation, enzymatic processes.	http://www.unical.it/
University of Cagliari.	Gasification for synthesis gas production.	http://www.unica.it/
University of Catania.	Energy crops. Biodiesel.	http://www.unict.it/
University of Foggia.	Policy for biorefinery; biodiesel production.	http://www.unifg.it/
University of Florence.	CFD modelling; gas turbines, bio-oil emulsions.	http://www.unifi.it/
University of Genoa.	Biomass gasification.	http://www.unige.it/
University of L'Aquila.	Biomass gasification. Fast pyrolysis.	http://www.univaq.it/en/
University of Messina.	Pyrolysis. Valorisation of furfurals.	http://www.unime.it/
University of Milano-Bicocca.	Energy production from forest biomass.	http://www.unimib.it/
University of Naples Federico II.	Biomass pyrolysis and gasification.	http://www.international.unina.it/
University of Perugia.	Combustion, gasification, pyrolysis of biomass.	http://www.unipg.it/
University of Pisa.	Second generation biofuels. Gasification.	http://www.unipi.it/english/
University of Rome – La Sapienza.	Gasification for synthesis gas production. Gaseous biofuels.	http://www.uniroma1.it/
University of Salerno.	Bioenergy and biomass.	http://www3.unisa.it/
University of Sassari.	Biomass production of energy.	http://www.uniss.it/
University of Teramo.	Biomass gasification.	http://www.unite.it/
University of Trento.	Biomass gasification.	http://portale.unitn.it/
University of Trieste.	Biocatalysis and enzyme technology.	http://www.units.it/
University of Turin.	Research on energy crops.	http://www.unito.it/
University of Tuscia.	Research on energy crops.	http://www.unitus.it/
<i>Latvia</i>		
Latvia University of Agriculture.	Biomass production for biogas in Latvia. Bioethanol.	http://www.aic.lv/
Riga Technical University.	Birch wood for bioethanol production.	http://www.rtu.lv/
Daugavpils University.	Biotar.	http://du.lv/en
<i>Luxembourg</i>		
University of Luxembourg.	Biomass.	http://wwwen.uni.lu/
<i>Netherlands</i>		
Eindhoven University of Technology.	Pyrolysis, biomass combustion gasification, catalysis.	http://www.wtb.tue.nl/ ; http://w3.tue.nl/
Technical University of Delft.	Thermo-chemical biomass conversion; biomass gasification and combustion and chemicals production; biochemical conversion.	http://www.3me.tudelft.nl/ ; http://www.kluyvercentre.nl/
University of Groningen.	Biomass pyrolysis, pyrolysis liquid upgrading, hydrodeoxygenation.	http://www.rug.nl/
University of Twente.	Flash pyrolysis, hydrothermal upgrading; supercritical water gasification, clean hydrogen production from bio-oil.	http://www.utwente.nl/

Table 4 (continued)

Institution(s)	Topic	Website
Utrecht University.	Bioenergy research, techno-economic analysis of bioenergy potential, biomass and land use.	http://www.uce-uu.nl/
Wageningen University.	Aquatic biomass and biochemical conversion of biomass; biochemical, enzymatic and biological conversion; fermentation processes.	http://www.bpe.wur.nl/ ; http://www.vpp.wur.nl/
Norway Norwegian University of Science and Technology, Trondheim. University of Bergen.	Pyrolysis. Catalysts. Upgrading bio-oil. Lignin solvolysis.	http://www.ntnu.no/english http://www.uib.no/
Poland Czestochowa University of Technology.	Advanced biomass combustion modelling.	http://www.imc.pcz.czest.pl/
Technical University Opole. Technical University of Lodz.	Combustion. Enzymatic saccharification of selected agro-industrial residues.	http://www.po.opole.pl/ http://www.p.lodz.pl/
Poznan University of Technology.	Gasification, combustion, biomass, land use, potentials.	http://www.fct.put.poznan.pl
Silesian University of Technology, Gliwice. University of Life Sciences, Lublin. University of Life Sciences, Warsaw. Wroclaw University of Environmental and Life Science.	Gasification for synthetic gas production. Research on energy crops. Research on energy crops. Production of erythritol from glycerol by various Yarrowia lipolytica strains.	http://www.polsl.pl/en/ http://www.ar.lublin.pl/english/ http://eureca.online.sggw.pl/ http://www.up.wroc.pl/en/
Portugal Instituto Superior Técnico (IST) Portugal. Polytechnic Institute of Portalegre. The New University of Lisbon. University of Aveiro.	Compounds and gas oil. Applied catalysis. Gasification for synthesis gas production. Research on energy crops. Biomass from mixed pine and eucalyptus forest.	http://www.ist.utl.pt/en/ http://www.ipportalegre.pt/ http://www.unl.pt/ http://www.ua.pt/
University of Beira Interior. University of Coimbra. University of Evora University of Porto.	Forest residues for bioethanol. Sustainable energy systems. Research on energy crops. Pyrolysis of wet wood.	http://www.ubi.pt/ http://www.uc.pt/ http://www.uevora.pt/ http://sigarra.up.pt/
Romania Petroleum Gas University of Ploiesti, Bucharest.	Hydrogen from renewable bioresources.	http://www.upg-ploiesti.ro/
Spain Carlos III University, Madrid. Polytechnic University of Madrid.	Gasification, raw syngas conditioning. Biomass gasification. Energy crops for heat and electricity.	http://www.uc3m.es/ http://www.upm.es/
The Complutense University of Madrid. University of Alicante. University of the Basque Country.	Fluidisation and gasification of biomass. Flash pyrolysis. Characterisation and modelling of pyrolysis processes.	http://www.ucm.es/ http://www.ua.es/ http://www.ikerbasque.net/
University of Catalonia. University of Cordoba. University of Extremadura. University of Granada. University of Jaén. University of Lleida. University of Santiago de Compostela. University of Seville. University of Valladolid, Luvia. University of Vigo. University of Zaragoza.	Biomass and waste gasification. Biodiesel production. Pyrolysis. Chars from holm-oak wood. Liquid biofuels from starch and sugar feedstocks. Furfural and ethanol from sugarcane bagasse. Biorefineries and industrial materials. Second generation ethanol from woody biomass. Fluid bed gasification of waste materials. Energy crops. Combustion. Solid biofuels. Fluidisation and gasification of biomass. Pyrolysis. Combustion.	http://www.upc.edu/eng http://www.uco.es/ http://www.unex.es/ http://www.ugr.es/ http://www.ujaen.es/ http://www.udl.cat/ http://www.usc.es/ http://www.us.es/ http://www3.uva.es/ http://www.uvigo.es/ http://wzar.unizar.es/

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Table 4 (continued)

Institution(s)	Topic	Website
<i>Sweden</i>		
Chalmers University of Technology.	Pyrolysis; biofuel combustion; sustainability of the energy system; carbon capture technology, ash characterisation.	http://www.chalmers.se/
Göteborg University.	Fluidised-bed system design, gasification, pyrolysis and combustion.	http://www.che.gu.se/
Karlstad University.	Nitrogen management in crops. Bioenergy in the forest industry, including fluidised beds and wood fuels.	http://www.kau.se/
Linköping University.	Bioenergy systems, CHP and energy in industrial applications.	http://www.ikp.liu.se/
Linnaeus University.	Gasification, catalytic upgrading and syngas cleaning.	http://lnu.se/
Luleå University of Technology.	Combustion and gasification systems; optimisation of energy systems.	http://www.ltu.se/
Lund University.	Biomass pretreatment and combustion, carbon sequestration in forests, anaerobic digestion, ash handling, extraction of lignin from black liquor.	http://www.iiiee.lu.se/ ; http://www.miljo.lth.se/ ; http://www.lth.se/ ; http://www.lumes.lu.se/
Royal Institute of Technology – KTH.	Gasification, pyrolysis and combustion of biomass, fuel catalysis and catalytic processes and membranes.	http://www.ket.kth.se/
Swedish University of Agricultural Sciences, Umeå.	Energy crops, agro and woody biomass for energy production.	http://www.btk.slu.se
Swedish University of Agricultural Sciences, Uppsala.	Biofuel chain of production, bioenergy system studies, bioenergy potentials and land use.	http://www.slu.se/
Umeå University.	Thermal energy conversion, biomass combustion and energy efficiency.	http://www.tfe.umu.se/
Växjö University.	Combustion, gasification and bioenergy system technologies.	http://www.vxu.se/
<i>Switzerland</i>		
ETH, Swiss Federal Institute of Technology, Zurich.	Biomass combustion.	http://www.ethz.ch/
EPFL, Lausanne.	Gaseous biofuels. Biological processing.	http://recherche.epfl.ch/
Lucerne University of Applied Sciences and Arts.	Biomass combustion.	http://english.hslu.ch/
University of Applied Sciences, Western Switzerland.	Biomass torrefaction.	http://www.hes-so.ch/
<i>United Kingdom</i>		
Aberystwyth University (IBERS).	Epigenetics in the bioenergy crop Miscanthus. Genotype and agronomic practices on N and P. Modelling of miscanthus genotypes and phenotypes.	http://www.aber.ac.uk/
Aston University.	Fast pyrolysis. Gasification. System design and optimisation. Analytical pyrolysis. Algae. CHP. Hydrogen production from synthesis gas. Biochar.	www.aston-berg.co.uk ; http://www.ebri.org.uk/
Bangor University.	Rapemeal valorisation: improving the economics of biodiesel manufacture.	http://www.bangor.ac.uk/
Cardiff University.	Experimental and modelling work on production and harvesting of biomass crops. Biomass combustion and gasification.	http://www.cardiff.ac.uk/ ; http://www.walesbiomass.org
City University.	Electricity supply for remote and rural communities.	http://www.city.ac.uk/

Table 4 (continued)

Institution(s)	Topic	Website
Cranfield University.	Experimental, modelling and techno-economic analysis of biomass & waste-fuelled CHP and thermo-chemical combustion of biomass.	http://www.cranfield.ac.uk/
De Montfort University.	Socio-economic analysis. Policy development, sustainability assessment, environmental decision making.	http://www.iesd.dmu.ac.uk/
Durham University.	Biodiesel production from photosynthetic microbes.	http://www.dur.ac.uk/
Harper Adams University College.	Fuel pellet production, handling and combustion of oilseed rape straw pellets; optimisation of bioethanol yield from oilseed rape straw.	http://www.harper-adams.ac.uk/
Herriot–Watt University.	The use of multifrequency dielectric spectroscopy to measure biomass in the presence of non-cellular particles.	http://www.hw.ac.uk/
Imperial College London.	Thermo-chemical conversion; carbon sequestration. Biorefineries, biochemicals, supply and demand relationships, policy and environmental studies.	http://www3.imperial.ac.uk/
King's College, London.	Biomass energy production.	http://www.kcl.ac.uk/
Loughborough University.	Rapemeal valorisation: improving the economics of biodiesel manufacture.	http://www.lboro.ac.uk/
Newcastle University.	Biological fuel cells.	http://www.ncl.ac.uk/
Queen Mary, University of London.	Electricity for remote and rural communities.	http://www.qmul.ac.uk/
Queens University, Belfast.	Steam reforming pyrolysis liquids.	http://www.qub.ac.uk/
Teesside University.	Biomass energy production.	http://www.tees.ac.uk/
University College London.	Biomass gasification & combustion.	http://www.ucl.ac.uk/
University of Aberdeen.	Techno-economic evaluation of bioenergy crops.	http://www.abdn.ac.uk/
University of Bath.	Biomass gasification. Biodiesel from waste oil.	http://www.bath.ac.uk/
University of Birmingham.	Sustainable biofuel.	http://www.ph.bham.ac.uk/
University of Bristol.	Biomass production and energy conversion in water scarce areas of India.	http://www.bris.ac.uk/
University of Cambridge.	Gasification and combustion, molecular biology of chloroplasts in plants, algae and plasmodium; photosynthesis and algal bioenergy. Proteomics and cell wall synthesis.	http://www.cheng.cam.ac.uk/ ; http://www.ceh.ac.uk/ ; http://www.bio.cam.ac.uk/
University of Dundee.	Identification of novel genes in grasses and Arabidopsis. Biohydrogen. Bioengineering, production and storage. Genetics underpinning biofilm formation.	http://www.lifesci.dundee.ac.uk/
University of East Anglia.	Socio and techno-economic analysis of all aspects of renewable energy, bioenergy specialisations.	http://www.tyndall.ac.uk/
University of Edinburgh.	Pyrolysis biochar systems.	http://www.ed.ac.uk/
University of Glamorgan, Pontypridd.	Sustainable grasslands for biological energy production. Biodiesel use.	http://www.glam.ac.uk/
University of Glasgow.	Single molecule studies on purple bacterial antenna complexes.	http://www.gla.ac.uk/
University of Greenwich.	Biomass pellets for co-firing.	http://www.gre.ac.uk/schools
University of Leeds.	Gasification. Ash analysis and characterisation. CFD modelling. Combustion fundamentals.	http://www.engineering.leeds.ac.uk/ ; http://www.see.leeds.ac.uk/
University of Manchester.	Biofuel vs food security. Gasification. Policy studies, environment studies.	http://www.manchester.ac.uk/

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Table 4 (continued)

Institution(s)	Topic	Website
University of Nottingham.	Systems modelling of input–output energy balances of bioenergy production at the farm-level.	http://www.nottingham.ac.uk/
University of Oxford.	Bioenergy from wheat straw.	
	Bacterial hydrogenases for biohydrogen technology.	http://www.ox.ac.uk/
University of Portsmouth.	Biofuels from plant biomass.	http://www.port.ac.uk/
University of Sheffield.	Renewable energy sources including biofuels. Combustion. CHP.	http://www.sheffield.ac.uk/
University of Southampton.	Sources for biological conversion.	http://www.soton.ac.uk/
	Anaerobic processing.	
	Modelling fast pyrolysis systems.	
University of Surrey.	Lifecycle analysis. Carbon footprints and embodied carbon.	http://www.surrey.ac.uk
University of Ulster.	Biomass gasification. System studies.	www.ulster.ac.uk
University of Warwick.	Microbial breakdown of plant wastes in a solid-state biorefinery.	http://www2.warwick.ac.uk/
	Fluid bed gasification and pyrolysis.	
University of York.	Developing biodiversity-friendly biofuels.	http://www.york.ac.uk/
	Anaerobic digestion.	
	Microwave pyrolysis. Biorefineries.	
<i>Useful websites</i>		
Find a PhD.com		www.findaphd.com/
German institutions		www.daad.de/
International		http://www.postgraduatestudentships.co.uk/
International		http://scholarship-positions.com/
International		http://www.scholarship-programs.org/
International		http://phdpdf-position.blogspot.com/
International		http://nextscholarships.com/
International		http://scholarship-positions.com/
UK		http://phdscholarship.co.uk/ ; http://www.jobs.ac.uk/

from the late 1970s to the late 1990s. Prolific growth was catalysed by strong government and industry support for renewable energy beginning with the ratification of the Kyoto Protocol and is continuing today. Seven observations about current MSc Course provisions in bioenergy can be made:

1. *Rate of introduction.* Masters Courses in or with a bioenergy content are being introduced at an accelerated rate. Of the 54 MSc Courses identified in this study, 44 of them, or 81%, began in the last five years (Fig. 1).
2. *Cross-European cooperative courses.* “European” Masters Courses have emerged that include study at two different universities in Europe and are taught in English. Increasingly, European universities are cooperating to deliver education in renewable energy. Some of the latest courses are provided by a consortium of universities to ensure that students are exposed to all aspects of renewable energy in Europe.
3. *Multidisciplinarity.* In the majority of Masters Courses, the multidisciplinary nature of the student body demands that course content is more descriptive and qualitative compared to traditional science and engineering programmes but incorporate social sciences, economics, business and law.
4. *Some Masters Courses offer an industrial placement, typically lasting six months.* One of the difficulties providers are facing in offering Masters Courses in renewable energy topics is that students are sceptical about job opportunities in these growing but immature markets. Industrial placements increase the attractiveness of the Masters by giving students job experience and contact with potential employers.
5. *Take-up rates of existing Masters Courses need improvement.* This review identified a possible shortage in the numbers of students that are actively pursuing postgraduate education in bioenergy. The EUREC MSc in Renewable Energy is a good example. In its first year, 2002–2003, the MSc had an intake of 19 students, seven of whom specialised in bioenergy; in the second year 25 students took the course; and in 2004–2005 the numbers rose to 40, ten of whom specialised in bioenergy. Over three years the number of students increased by 100% but the number of students studying bioenergy only rose by 40% [5].
6. *The recent introduction of focussed Masters Courses in bioenergy.* A recent development is the provision of Masters Courses that concentrate wholly on biomass and bioenergy. This review identified four such courses, one in France, another in Finland and two European courses, offered by a consortium of universities from three or more EU Member States. Providers are also beginning to offer bioenergy specialisations or tracks as part of a Masters in renewable energy; three such courses were identified in the mapping exercise.
7. *Language.* In addition, European countries where English is not the native language, are beginning to offer more English-language Masters Courses to appeal to an international student body.

4.2. PhD courses

PhD research in bioenergy in Europe is thriving. 231 providers of PhD studies in bioenergy have been identified in the EU27 plus Norway and Switzerland. A full list of providers can be found in Table 4 and a geographical summary is given in Fig. 3.

4.2.1. PhD courses findings

During the mapping exercise, two observations about current PhD course provisions in bioenergy were made.

1. *PhD study is the most established field of bioenergy education and training.* PhD research into the entire bioenergy chain, from the production of energy crops and wood residues through the conversion of biomass by thermal and biological processes, to the use of the end products, began to take off just after the first oil crises in the 1970s and has been growing since then. There are an increasing number of specialist chairs (professorships) in bioenergy.
2. *Recruitment into PhD studies in bioenergy needs further investigation.* Some PhD providers consulted during the review identified difficulties in recruiting and retaining enough talented PhD students. A more general benchmarking exercise by the EC anticipated a shortage of qualified researchers in science and technology in Europe. From 1996 to 2001 the number of students engaged in PhD studies in Europe has stayed the same or increased slightly in some EU countries, but not enough to satisfy a growing demand for researchers [6]. Moreover, bioenergy competes with other science and technology fields to attract the best students in Europe and internationally. As the bioenergy research area and industry continues to grow, more highly skilled PhD students will be required. More research into take-up rates of PhD courses is needed to anticipate and address any future skills gaps.

4.3. Short courses

The initial Bioenergy NoE mapping exercise identified over 40 Short Courses in bioenergy in the EU, however the availability and courses offered fluctuate considerably and overlap with

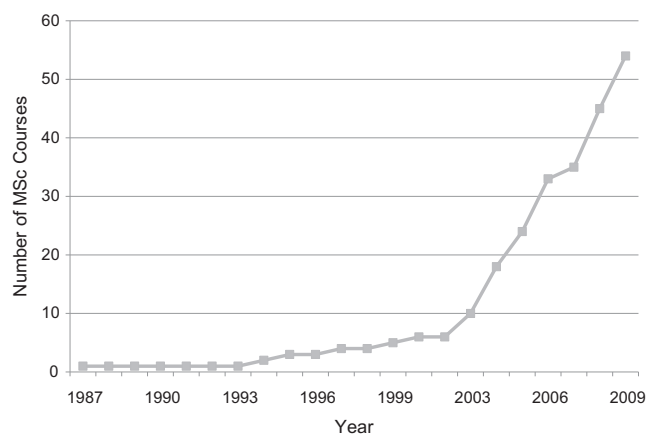


Fig. 1 – Growth of MSc Courses in or with bioenergy in the eight Bioenergy NoE countries. Table 3 provides a current listing for the EU27 plus Norway and Switzerland.

specialist conferences and workshops which makes identification and definition difficult. Short Courses are often the ideal method to introduce bioenergy and biomass processes and technologies to potential stakeholders, acquire specialist expertise in specific areas and update bioenergy professionals on the latest technological developments. Short Courses in bioenergy can be divided into two categories:

1. Professional Development courses for bioenergy professionals (managers, researchers, designers, planners, engineers, installers and policy makers) to acquire expertise in specific areas.
2. Training courses to provide bioenergy stakeholders such as farmers with more knowledge of biomass production and/or bioenergy technology. Provisions include workshops, seminars and summer schools. These courses provide the background required to become involved in bioenergy production.

4.3.1. Short course findings

There are two main observations about Short Course provisions in bioenergy:

1. Short Courses are limited in the types of courses provided, locations, and regularity. This is a fairly new field compared to MScs and PhDs but with considerable growth prospects. A diverse range of courses were identified but the locations are limited, with many courses catering to regional audiences, and many courses are only offered sporadically. Of the courses identified, nearly half are geared to bioenergy professionals. Many are provided by a university as 'Continuing Professional Development' (CPD) courses. Course content is often taken from an existing MSc programme in engineering or renewable energy, thus courses on offer may not always cater specifically to industry needs or take real work situations into account. The content of these courses is either highly technical or provides a general introduction to renewable energy technologies. There is a lack of courses on new developments in the bioenergy field for researchers and scientists and renewable energy or bioenergy courses aimed at high-level policy makers.
2. Short Courses are not widely marketed. Mapping Short Courses proved the most difficult part of the review

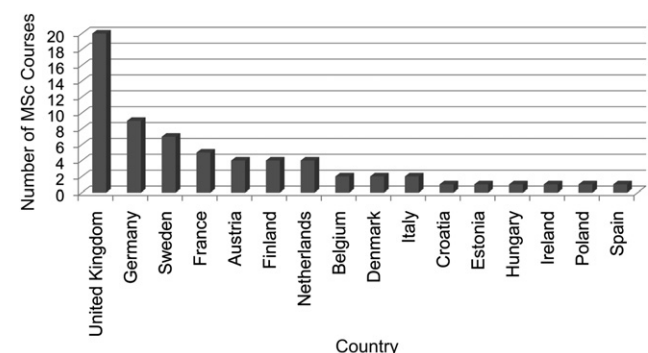


Fig. 2 – Geographical locations of Masters Courses in or with bioenergy 2009.

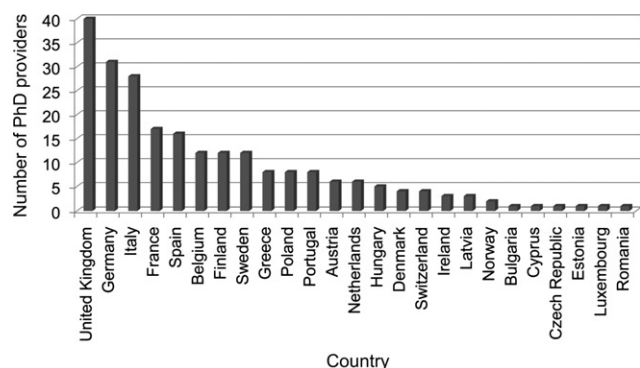


Fig. 3 – PhD providers in the EU27 plus Norway and Switzerland.

because they do not seem to be widely promoted or advertised.

5. Conclusions and recommendations

5.1. Masters and PhD courses in bioenergy

Provisions in bioenergy education and training in Europe have been rising quickly over the past five years at the Masters, PhD, and to a lesser extent, Short Course level. Provision and take-up of courses can be improved through better marketing and promotion, and increased collaboration among course providers in Europe.

Evidence from this review suggests a shortage of students on some of the existing MSc and PhD courses. Low take-up rates could be due to a number of factors including job opportunities elsewhere, costs and time involved in pursuing advanced education, and lack of awareness of career opportunities in the bioenergy field. A few course providers have testified that students have difficulty committing to higher education in bioenergy because the job opportunities for those with an MSc or PhD in this area are still uncertain and not well defined. Better dissemination and promotion of bioenergy higher education, increased financial support via scholarships programmes, and more visible demand from industry for skilled graduates could help to attract more students to advanced bioenergy studies.

The review flagged up a disconnection between bioenergy course providers in Europe. Some MSc Course providers expressed strong interest in learning about similar activities in other universities, while others asked for help to promote their courses to a wider audience. A conference or workshop that brings together course providers could help to improve Masters Courses in renewable energy or bioenergy by sharing best practices.

Increased collaboration between PhD providers can improve visibility of bioenergy studies and offer students a wider range of expertise and facilities. Summer Schools and guest lectures are important ways to build links with the active research community and industry, decrease the isolation felt in pursuing lone work, and learn about the latest developments in the field. Innovative ventures like the Nordic

Graduate School of Biofuel Science and Technology, run by four universities in Denmark, Sweden, Finland and Norway, should be held up as best practice for other PhD providers in Europe [7].

5.2. Short courses in bioenergy

Short Courses are seen as a substantial growth area for bioenergy education and training and while some courses exist, the regularity of provision and location of courses is limited. Increasing both the numbers and diversity of courses on offer is necessary to cater to bioenergy professionals and to stakeholders throughout Europe. Eighty per cent of the Short Courses mapped began after 2000, and it is expected that this strong growth trend will continue over the next five years and this can help to fill in some of the gaps identified.

Short Courses for researchers and experts in the field are minimal despite evidence of substantial demand. In 2006 the Bioenergy Network of Excellence conducted a survey asking researchers in the consortium if they require Short Courses in specific bioenergy topics. Of the 33 full-time researchers who completed the survey, over half requested training in specific areas of bioenergy and biomass production. There is clearly a niche market in the area that will only grow as commercial implementation of bioenergy systems grows.

6. Summary

The conclusion is that there has been rapid growth in MSc Course offerings in Europe over the last five years, but where data is available, enrolment has been quite low suggesting that there is an oversupply of courses and that course organisers are being optimistic in their projections. Existing provisions in Europe at Masters and PhD levels are clearly more than sufficient for short term needs, but further work is needed to evaluate the take-up rate. To ensure that talented graduates are attracted to these programmes, better promotion, stronger links with research and industry, and more collaboration among course providers are needed. Short Courses and similar training activities of two to five days are an excellent way of meeting post-experience training needs but require further growth and development to serve the needs of the bioenergy industry and research community.

Please note: while every effort has been made to include all activities in this article, there are likely to be some omissions or errors and the authors would be pleased to hear of these so that an improved version can be published later. Contact Tony Bridgwater (a.v.bridgwater@aston.ac.uk) or Irene Watkinson (i.i.watkinson@aston.ac.uk).

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organisations to foster excellence in European bioenergy research and industry. One of the key activities of this Network is to evaluate and promote education and training activities in bioenergy that will grow NoE researcher expertise and, on a wider level, build excellence in higher education and training in bioenergy in Europe.

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